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Testing MIMO Devices Over the Air

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I. Introduction

Multiple Input Multiple Output (MIMO) technology is an attractive and promising solution to enhance the performance of wireless systems in terms of data throughput and reliability. New wireless generations like LTE, LTE- Advanced and WiMAX require the employment of multiple antennas in mobile terminals.

In MIMO systems, both the propagation channel conditions and the antennas have significant impact on the system performance. Also, signal processing algorithms and scheduling in real devices may have a strong impact. In order to cover all these aspects and to include all additional performance influencing factors in a final practical product, it has been suggested to use so-called Over-The-Air (OTA) testing.

Standardization work for the development of the MIMO OTA test methods is currently ongoing. Several approaches are proposed and are still under investigation. One of the candidates is the multi-probe anechoic room based MIMO OTA testing method which is considered the most promising and technically advanced approach [1].

The aim of OTA testing is to test final devices (products) in a realistic radio environment. To be meaningful the test should be both repeatable and manageable in practice, and at the same time yield results that are comparable to live network performance.

The following gives an overview of recent OTA related activities in the Antennas, Propagation, and Radio Networking (APNet) group at Aalborg University.

II. Evaluation in Live Systems

OTA testing in the anechoic room is typically based on well accepted channel models, such as WINNER or SCME, which the setup is emulating in an approximate way. Therefore, two overall types of sources of inaccuracies exist, the first relating to the ability of the model to mimic the real world, and the second relating to the accuracy of the model emulation in the anechoic room.

With the purpose of obtaining reference results, a series of measurements in a live LTE network have been carried out. In order to also allow detailed analysis of the channel conditions, radio channel sounding have been performed in parallel. Although the LTE system has some built-in facilities for obtaining channel information, a dedicated channel sounder has more advanced possibilities.

Some of the challenges of the parallel channel sounding and live network measurements are

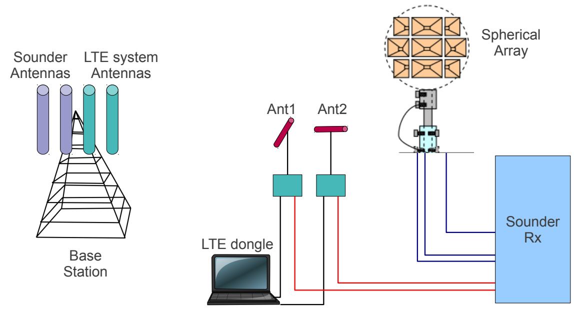

Fig. 1. Schematic of parallel sounding and device performance evaluation in a live LTE system.

- The channel sounder cannot easily use the same frequency band as the live LTE system, due to interference.
- Synchronization of the sounding system and the LTE network data acquisition is made difficult by issues such as the unknown and possibly varying logging frequency of the dongle. Quasi-synchronous operation may be possible using the time-stamping of the logging tool. Initially, the performance comparison is made only on an average basis.
- Using the same BS antennas for both the live network and the sounding system is possible technically, but requires cooperation with an operator. For simplicity in the initial phase, a parallel set of antennas are used for the sounding.
- The logging of LTE parameters from a dongle modem is only done on a best effort basis, meaning that data is only logged when the dongle is not busy maintaining the LTE link.

An overview of the two parallel systems is shown in Fig. 1. For the LTE network, a single cell was used, located in the city center of Aalborg, Denmark. The BS was on top of a high building overlooking the surrounding buildings. On the mobile station side a Samsung LTE dongle (GT-B3710) was connected to a laptop running the Rohde Schwarz Romes logging software. The software is able to log various data from the dongle during a connection, such as rank indicator, CQI, resource blocks, and throughput.

Two external antenna connectors on the dongle are used so that different types of device antennas can be tested. Using splitters, the antennas are connected to both the LTE dongle

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Fig. 2. Practical setup of the spherical array of dual-polarized horn antennas (in the back of the car trailer) and the four pairs of dipole antennas used for both the LTE dongle and the channel sounder (mounted on the white styrofoam).

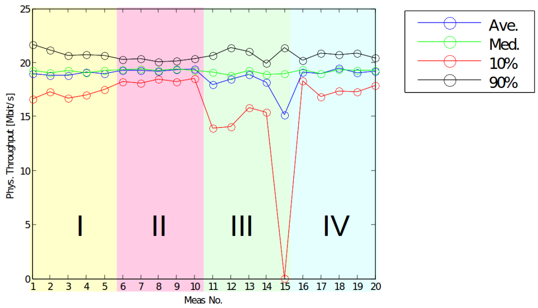

Fig. 3. Example statistics of LTE system throughput. Percentiles for repeated measuremens with antenna pairs I-IV.

as well as the channel sounder, allowing the LTE performance and channel properties to be investigated in parallel. Four pairs of antennas are connected via a switch allowing easy connection of the active pair used for measurements.

In addition, a separate antenna array is connected to the sounder. The array consists of 16 dual-polarized horn antennas arranged to point in different directions on a sphere. This enables analysis of the directional properties of the received signals.

The antenna setup is shown in Fig. 2. The sounding equipment and the LTE dongle/laptop is inside the car. With this setup, measurements have been made in different locations 500-800 m from the BS. Fig. 3 shows some example throughput statistics.

III. Evaluation in the Anechoic Room

In the OTA testing carried out in an anechoic room, the objective is to emulate an artificial radio environment using a number of probes. The probes are typically arranged in a ring around a test zone, inside which the device is located. The phase and amplitude of the signal transmitted from each probe is altered in a way, typically using a channel fading emulator, that the combined signal received by the device from all the probes has the desired properties with respect to, *e.g.*, angle of arrival (AOA), Doppler rates, and correlation. Fig. 4 shows an experimental setup, based on 8 dual-polarized horn antennas.

Since OTA testing is a relatively new subject many important issues have not been studied sufficiently for correct and meaningful OTA testing. In the near future the APNet group will host a large setup with up to 64 probes and 32 channel emulator branches. Many issues are planned for investigation, such as influence of the number of probes, location of the probes, polarization, *etc.*

In an example of a study the target was to emulate a plane wave inside the test zone, resulting in specific probe weighting depending on the AOA, assuming ideal probe locations. Fig. 5 shows statistics of the phase errors introduced when the location of a probe is offset tangentially to the circle. Similarly, radial offsets have been studied as well as incorrect orientation of a probe horn antenna.

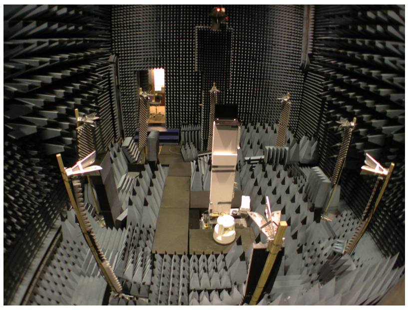

Fig. 4. Ring of 8 dual-polarized probes in anechoic room for OTA measurements. Note, the perspective is distorted.

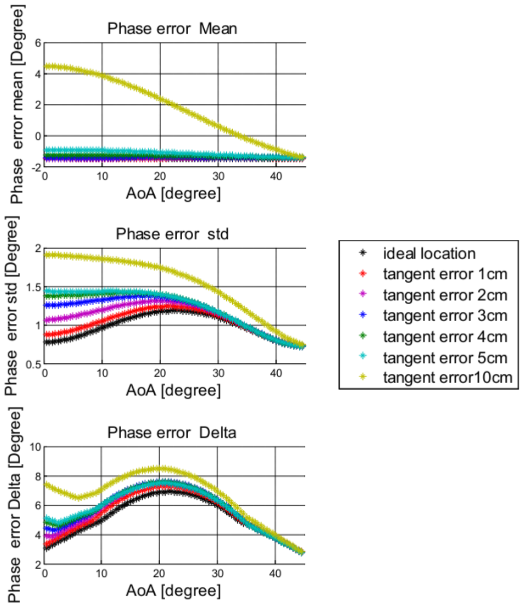

Fig. 5. Example statistics of the error in the plane wave phase due to incorrect probe location (tangential offset).

IV. Summary

A system for performance evaluation of LTE devices has been presented, with evaluation in both a live network and with a channel sounder. The results serve as reference for OTA evaluations in the anechoic room based on multi-probe setups.

References

[1] 3GPP, “Measurement of radiated performance MIMO and multi-antenna reception for HSPA and LTE terminals (release 11),” 2011, 3GPP TR 37.976 V1.5.0 (2011-05), R4-112505.

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